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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

The Teaching of Mathematics to Physicists

The Institute's report, *The Teaching of Mathematics to Physicists*, was first published in 1944 and has twice been reprinted to meet the steady demand for it. It has now been decided that the time has come to consider the revision and possible extension of the report and a panel consisting of Dr. A. W. Gillies, Dr. M. R. Hopkins, Professor L. Howarth, Dr. H. Lowery, Dr. J. Topping and the Deputy Secretary has been appointed to do this. If any members have comments or suggestions that they would like to bring to the notice of the panel they should send them to the Deputy Secretary.

Conference on Magnetic Resonance in Solids

The Radio Frequency Spectroscopy Committee is organizing a Conference on the Applications of Magnetic Resonance to Solid State Physics at King's College, Newcastle upon Tyne (University of Durham), on Monday and Tuesday, September 22 and 23. The program will include : electron resonance of colour centres and iron group impurities in ionic crystals, nuclear resonance in ionic solids, electron spin, nuclear and cyclotron resonance in semiconductors. Further particulars and application forms may be obtained from Dr. E. E. Schneider, University of Durham, King's College, Newcastle upon Tyne.

Rheology Conference

The British Society of Rheology is organizing a conference on " Fracture, Fatigue and Failure " to be held at The University of Leeds on January 8 and 9, 1959. Further information can be obtained from the Honorary Secretary of the Society, 52 Tavistock Road, Edgware, Middlesex.

Physics Research at Harwell*

By B. F. J. SCHONLAND, C.B.E., M.A., Sc.D., F.R.S.

(*Director, Atomic Energy Research Establishment, Harwell*)

I HAVE taken on a rather difficult task in talking about physical research at Harwell. Harwell is, I believe, the largest single non-military atomic energy research establishment in the world and the physicists there are its largest group of professional workers. To recite all the activities on which they are engaged would take a very long time. What I hope will interest you will be to give a general picture of what is going on and what is planned in physics at Harwell and to select for more detailed treatment some items which, to me at least, are of particular interest.

To start with the general picture : the functions of Harwell are to obtain basic knowledge and to follow up new and fruitful ideas for two purposes—firstly the economic development of nuclear power and secondly the applications and use of radio-active isotopes. With radioactive isotopes I shall not be able to deal at all, simply because there is not time. But by leaving out this aspect I do not imply that the use of radio-isotopes is likely to be less important than atomic power ; it is quite on the cards that it will be more important.

Harwell may be described as having an academic " inlet " end where basic ideas arise and a practical and technological " outlet " end. The objective of cheap and safe atomic power is met at the outlet end in the finished study of the feasibility of a particular reactor system. In such a study the physicists—here called reactor physicists—join with chemists, metallurgists and research engineers in a reactor project. The project puts together in the best and most economic form possible the basic ideas of a new reactor system and the many complicated and laborious technological investigations on its components, to see whether the new system is worthwhile. It does not design a final reactor prototype ; it only considers whether it is feasible and in what form. This task may require a series of experiments on various " mock-up " forms of the proposed reactor, an " exponential " test assembly of the components, a " zero energy " assembly of low power and finally a medium power (say 10 MW) reactor experiment, capable of much modification and easily adaptable by the experimenter. The principles of the Calder Hall type of graphite-moderated reactor were first worked out in this way. Its possible variants and successors are at present being examined. In such projects the reactor physicist is a key man, for the physical problems involved are extremely complex.

The chain reaction of atomic fission as you know requires that each fissioning atom should give rise to another such, in spite of casualties and losses to the neutrons produced in the original fission process. There is so little easily fissionable material in natural uranium and there are so many ways in which neutrons can be lost in a reactor system that it is surprising that a natural uranium chain reaction can be obtained at all. At birth the neutrons have an energy of between 1 and 2 MeV. They cannot be used effectively to produce a chain reaction in natural or near-natural uranium until they have been slowed down to " thermal " energies of the order of 0·03 eV. The slowing down process must be carried out by elastic collisions with nuclei of some material of low atomic mass. This material must be one which does not capture neutrons in nuclear resonance traps on the way down from 1 MeV to ·03 eV. Uranium 238 has a set of traps of this kind between 100 and 6·5 eV (with σ_a between 4,800 and 8,000 barns).†

For this reason, if natural uranium is to be used it is employed in the form of thin rods placed in a lattice inside a " moderating " material (such as graphite or heavy water) which has a very low capture cross-section and which slows the neutrons down within a fairly short distance. The slowing-down property is expressed by $M = \xi\sigma_s/\sigma_a$ where ξ is a measure of the average energy loss per collision, σ_s the scattering cross-section and σ_a the absorption cross-section. Some values of M are :—

Heavy water	12,000
Graphite	170
Beryllium	159
H_2O	72

In the case of graphite moderation, the system is large in size compared with the mean free

*A lecture given to the London and Home Counties Branch of the Institute on January 15, 1958

† σ_a is the cross-section (target-area) for absorption ; 1 barn = 10^{-24} sq. cm.

path of the neutrons and diffusion theory can be used to calculate the parameters of the reactor with fair accuracy. The disturbances caused by control rods and coolant channels can be treated by perturbation methods. But newer forms of reactor are now required which are much smaller in size. For these diffusion theory is no longer a good enough approximation and the reactor physicist must employ the complete Boltzmann transport equation. Ordinary water, for example, gives rise to grave computing difficulties. Hydrogen has a high value of ξ and a large σ_s and hence "thermalizes" a fission neutron in 18 nuclear collisions (as against 115 for carbon). But since its capture cross-section is 100 times that of carbon, water-moderated systems must employ uranium enriched in U^{235} to counteract the absorption in the moderator. For calculations of the kind I have mentioned the reactor physicist depends greatly on his mathematical colleagues and they in their turn need to operate the most modern digital computers.

Other difficulties exist. The metallurgist encases (or alloys) the uranium fuel with new and strange metals to withstand its changes in form and in strength under irradiation and its reactions with the coolant. Both the metallurgist and the engineer require rods and tubing of some strength in the parts of the structure. Great circumspection and much calculation and experiment are needed if their needs are to be met economically. Iron ($\sigma_a = 2{\cdot}5$ barns) is ten times as neutron-absorbent at thermal energies as aluminium, which is itself four times as absorbent as magnesium and 23 times as absorbent as beryllium ($\sigma_a = 0{\cdot}01$ barns). Graphite has σ_a less than ·005 barns.

Having settled with the engineer, the metallurgist and the chemist on the best compromise between all these conflicting needs, the reactor physicist is still not free from worry. He has to consider the behaviour of the reactor as a working, kinetic, system. The fission process itself creates products in the uranium fuel which make his hair stand on end. One of these, Xe^{135}, has a (thermal) σ_a of $3{\cdot}5 \times 10^6$ barns, absorbing neutrons with ease to form the closed shell nuclide Xe^{136}_{54} with the "magic" number of 82 neutrons. Another is Sm^{149} with $\sigma_a = 5{\cdot}3 \times 10^4$ barns. Plutonium itself forms non-fissile absorbing isotopes Pu^{240} and Pu^{242}. The behaviour of the reactor alters considerably with time, as these and other materials are formed in the fuel. Where resonances occur not far from the operating temperature of the reactor—as particularly in the case of plutonium—increase of reactor temperature causes them to be broadened by the increased thermal motion of the fuel atoms. This effect has important consequences for the temperature coefficient and kinetic behaviour of the system.

The reactor physicist obviously has to be a highly skilled, patient and ingenious person. Even to-day he is often not able to give an accurate enough estimate of the size and the enrichment in U^{235} required of a reactor core. Some cores turn out to be unnecessarily large (Calder Hall is one example, though this was hoped for and is not a disadvantage) and some too small. Apart from the difficulties of the calculations and measurements involved, the reactor physicist still needs much more extensive and more accurate information on nuclear cross-sections for neutron absorption, scattering and fission at various energies and on the slowing down spectrum of neutrons in a reactor.

Several devices, including the neutron crystal spectrometer, have been used to obtain nuclear cross-section data with nearly mono-energetic neutrons. But this is a difficult and limited method of approach to the problem. The ingenious "time of flight" method, which has been developed at Harwell by Egelstaff and Poole, starts instead with pulsed neutron beams from a pile with a wide range of energies and sorts out the energies after instead of before transmission through the material under test. The pulse of transmitted neutrons travels a considerable distance down an evacuated tube and these are straggled out in terms of energy by the time they take to reach a neutron detector at the end of the tube. The detector output is examined and recorded (by rapid electronic gating) at short consecutive intervals of time of a quarter of a microsecond each. As many as 1,000 separate intervals can be examined, constituting measurements on 1,000 different velocity groups. The neutrons passing out of the DIDO reactor are arranged to pass down a flight tube 100 metres long. As in earlier measurements with BEPO the necessary pulses are provided by fast shutters (choppers) rotated at high speed.

In another and more comprehensive form the neutron pulses are produced from a uranium target by gamma ray excitation, the target being bombarded by electrons (and hence by gamma rays) from a pulsed linear accelerator. This technique, which can cover a wide range of neutron energies, is being developed further to give very intense beams of neutrons from a target of nearly pure U^{235}. The pulsed chain reaction

so obtained will multiply the original neutron intensity ten-fold. This "neutron booster," which will be in operation this year, employs a 28 MeV electron linear accelerator with an electron current of about an ampere during the pulse. The dissipation of energy in the target will be about 40 kW, the accelerator employing 6 klystrons each of 6 mW rating. From the target, flight tubes up to 200 metres long extend in a number of directions so that several experiments may be made at the same time. The method is also in use by Poole in a most ingenious way to obtain the neutron spectrum in a reactor lattice (fuel plus moderator) by pulsing the centre of the lattice with externally supplied neutrons and measuring time of flight in different directions.

Measurements of nuclear constants often require thin sheets of material in the form of individual separated isotopes, for resonance nuclear energy levels and neutron absorbtive properties alter markedly from one type of nucleus to the next. The weakly radioactive or stable isotopes needed for such measurements are obtained from the large Harwell electromagnetic separator. The reactor problems raised by the growth of fission products and of plutonium in fuel elements have led to a further requirement for such radioactive isotopes. These are needed in milligram quantities and to obtain them a special electromagnetic separator—HERMES—has been constructed and is at present engaged on separating Pu^{239}, Pu^{240} and Pu^{241}. Since plutonium is very toxic this large machine has to be fully enclosed and serviced by men in heavy rubber frog-suits.

For cross-section measurements at energies in excess of 50 keV it is necessary to produce neutrons by means of fast proton or deuteron reactions with suitable elements. For these purposes we have available a 5 MeV Van der Graaf machine, built by Dr. W. D. Allen, and other high-voltage accelerators. At the present time we are getting ready a 10-12 MeV Van der Graff machine in association with A.W.R.E. Aldermaston who have a similar requirement. This will have two vertical discharge tubes on top of one another, the central junction being at +6 million volts with respect to the upper and lower earthed ends. The ion-source at the upper end should give at least 10-15 microamps of negative (molecular) ions of hydrogen or deuterium. After passing down the upper tube they will be stripped of electrons on a foil or a mercury jet and pass on as positive (atomic) ions to the bottom exit. Here a rotatable deflector will turn the particles through 90° to any one of three shielded target rooms at the base of the installation.

My account has now passed from the technological "outlet" end of Harwell's activities by way of reactor physics and nuclear cross-section studies to the more basic "inlet" ends where new ideas are developed in academic freedom. These high energy machines together with studies in cosmic rays provide Harwell and its university associates with the opportunity to carry out a great deal of fundamental work in nuclear physics. How necessary it is to be on the alert for new possibilities is illustrated by Alvarez's recent discovery of a fusion chain reaction carried on by μ mesons at ordinary temperatures

$$p + d + \mu^- \rightarrow He^3 + 5{\cdot}5\ \text{MeV} + \mu^-$$

It does not look as though this particular reaction could be an economic form of nuclear power (the factor against it is about 100) but it only goes to show what can happen.

As an example of work recently undertaken with these machines I will quote the determination of the energy levels of N^{16} produced in excited nuclear states by firing fast deuterons at N^{15}; $N^{15}(d, p)N^{16}$. These levels and their transition probabilities have been compared with calculations by Elliott and Flowers, based upon the shell model, with most satisfactory results. The large field of energy levels is very important to a knowledge of the principles which govern the behaviour of nucleons and a variety of nuclear reactions $\{(d, p)\ (n, n')\ (p, n)\}$ are used to obtain the data while much attention is being devoted by our mathematical physicists to elucidating them in terms of nuclear structure.

Harwell is now adding to its armoury of high-energy accelerators a proton linear accelerator which will provide proton currents of several microamperes at 50 MeV energy. Injection is from an ion-source provided with a 500 keV Cockcroft-Walton machine and acceleration is in three stages 0·5–10 MeV, 10–30 MeV and 30–50 MeV through drift tubes in three cavity resonators. With this machine studies will be made of proton-proton and proton-neutron interactions in an energy region where a great deal of information is needed. The large beam intensities will make accurate electronic observations of scattering phenomena easy. The energy of the beam will be very precisely known (49·71 ± ·05 MeV is the present estimate). Though an equivalent machine (68 MeV) exists in Minnesota we should have a factor of 100 times more in intensity.

Comparatively few measurements have so far been made on nucleon-nucleon scattering in the energy region 10–100 MeV. This is an especially

important region for the detailed study of nuclear forces and one in which we can expect to learn a lot by means of accurate observation. It is hoped to provide this machine with beams of polarized protons.

One interesting nuclear reaction which is planned is the sampling of single particle states of neutrons by picking them up with protons to form emergent deuterons.

The proton linear accelerator will be operated by Harwell on behalf of the new Rutherford High Energy Laboratory of the National Institute of Nuclear Sciences under Dr. Pickavance who is building it. Teams from Harwell as well as from the universities are preparing equipment to work with it late this year.

Another machine of much higher energy, a 7,000 MeV proton-synchrotron, is being designed and built for the Rutherford Laboratory and should be ready for use in 1961. This will employ a 15 MeV proton linear accelerator as injector, with a 600 keV Cockcroft-Walton set on its "gun" The magnetic race-track round which the protons will circulate will be 160 feet in diameter. The magnet itself will weigh 6,000 tons. The pulsed magnet power supply will have a peak output of 120 MVA ; pulses will follow one another at intervals of 2 seconds. The machine will provide the universities of this country with a much-needed facility for high energy work including the study of the " strange " heavy particles, the energy threshold for whose formation is about 1½ MeV.

It is the co-existence of basic fundamental studies of this kind and of technological and engineering work which gives Harwell its special character and is its great source of strength. One side reacts on the other to remarkable effect. To take one example : Atomic power reactors which use metallic uranium are limited in the temperature at which they can operate by the effects of gaseous fission products, xenon and krypton. After long service at high temperatures the fuel cartridges tend to swell. The metallurgist can at present meet this threat to the integrity of the fuel element in various ways including enclosing it in strong cans. For still higher temperatures he recommends ceramic fuels such as oxides. But it is interesting and valuable to know how and where in the metal these isolated gas atoms coalesce into bubbles. In an attempt to find the answer Dr. Barnes under Dr. Cottrell has bombarded a piece of pure copper in the University of Birmingham cyclotron at a temperature below 200°C with 40 MeV alpha particles. When the block was sectioned no helium bubbles were seen until it was heated to 600°C. After heating for an hour at 800°C, bubbles were observed not only on the periphery of the helium-containing band (where the majority of the particles come to rest) but also, and in profusion, along the grain boundaries in this region. The extra space required for bubble formation can only be obtained by capturing large numbers of vacancies, which is easiest to do by driving away the labile surface atoms on the grain surfaces. There are also for some at present unexplained reason circular regions of bubbles within the grains which appear to be point sources of vacancies.

Although the swelling effect has been avoided in the metallic fuel elements used in the Calder Hall type of power station, it sets a limit to metal temperatures in more advanced forms of reactor and the knowledge gained from these experiments is valuable. It also has an application to the use of beryllium in reactors, for this metal generates helium under neutron bombardment.

Another example is the use of mass-spectrometer and radio-activation techniques of analysis to determine the ages of rocks by the decay of uranium and thorium to lead and of Rb^{87} to Sr^{87}. Dating of geological formations by this means is becoming an exact science and one of growing interest to geologists, particularly those concerned with finding ore deposits. The Atomic Energy Authority has an obvious interest in these matters for the Geological Surveys who help in finding uranium ores require a rock-dating service. Within the limits of its resources Harwell is now providing assistance in lead and rubidium age-determinations and is helping the Geological Department of the University of Oxford to develop the K^{40}–A^{40} method of dating micas.

Collaboration between the pure and applied sides of research can also work in reverse. Beta-ray spectra are studied at Harwell as a means of identifying radioactive substances. The equipment has recently been used by Cavanagh in some beautiful fundamental work to provide further evidence for the failure of the parity-principle when beta rays are emitted from radio-active cobalt, and work in this field is continuing.

I should like to turn for a moment to two ingenious and very useful developments in experimental techniques with neutrons. Neutrons can of course only be detected indirectly. The standard method of measuring their energy E_o in laboratory experiments has until recently been to pass them through hydrogen (or hydrogenous material) and to measure the energy of

he recoil protons from neutron-proton collisions. But this is $E_o\cos^2\varphi$ where φ is the angle between incident neutron and recoil proton and in spite of various tricks one cannot determine φ and hence E_o with the accuracy needed.

Batchelor and Morrison at Harwell have made it possible to eliminate φ by using a nuclear reaction.

$$He^3 + n + E_o = H^3 + p + E_p + E_T + Q$$

where Q is the energy of the reaction. Since E_p and E_T, the energies of the resulting proton and triton are converted into gas ionization, a proportional counting tube filled with He^3 gives an unambiguous measure of the energy of an incident neutron.

Neutron counters using solid or liquid scintillators have the advantage over gas counters of much greater density and hence of greater detecting efficiency. But since they also give scintillations from the electrons produced by gamma rays it is not usually possible to count neutrons with them in the presence of gamma rays. G. T. Wright showed that the decay time of the two scintillation effects is different, the proton-produced pulses of light from neutrons decaying more slowly, and Brooks at Harwell has made use of this to separate neutron and gamma scintillations. His device uses a cathode ray oscillograph whose X output via a photomultiplier is proportional to the total light intensity from the particle and whose Y output is a function of intensity and the shape of the decay surve.

This ingenious trick has made it possible to measure accurately the yield of fission neutrons from U^{235} as a function of incident neutron energy from 0·3 to 100 eV in spite of the gamma rays emitted as a result of neutron capture.

I have left to the last the best example of the value of a technological organization which is given considerable freedom to do fundamental research. This is controlled thermonuclear fusion. Power from fusion can be envisaged from any one of three hydrogen nuclei reactions (the nuclei must be isotopes of hydrogen to enable their energies to overcome initial Coulomb repulsion). Thus we may have

(*a*) $D + D = He^3 + n + 3{\cdot}6$ MeV

(*b*) $D + D = T + p + 4{\cdot}0$ MeV or

(*c*) $D + T = He^4 + n + 17{\cdot}6$ MeV.

The first two have reaction cross-sections of 0·03 barns at 100 KeV ($T \simeq 10^{6\circ}K$) ; that of the third is 5 barns. For various reasons the third, though the easiest to achieve, is not the best for initial experimentation. Collisions between these nuclei involve two processes: fusion and elastic scattering. At low energies the latter is the more likely ; the elastic scattering cross-section σ_e is ten times the fusion cross-section σ_r even at energies of 100 keV. Thus to fire an accelerated beam of deuterons into a stationary target containing deuterium is simply to waste the energy of the incident beam in heating the target. One way of avoiding the difficulty is to leave the fusion process to thermal collisions between the nuclei and to heat the gas beforehand by electrical discharge until it reaches a temperature such that σ_r is comparable with σ_e. This can happen since

$$\sigma_r \propto \frac{1}{E} e^{-\frac{1}{\sqrt{E}}}$$

Where E is the thermal energy of the deuterium nucleus while

$$\sigma_e \propto \frac{1}{E^2}$$

The reaction may then be sought in a heated gas, so hot indeed that it is a pure plasma containing nothing but stripped nuclei and free electrons. That fusion can then raise its temperature still further arises from the fortunate circumstance that after a critical temperature is reached the rate at which energy is released in fusion can exceed the rate at which it is radiated by bremstrahlung from the electrons. For the former varies as $e^{-1/T}$ and the latter as $T^{\frac{1}{2}}$. (Stefan's law does not apply ; this is far from a "black" body.) The critical temperature for the D—D reaction is $1{\cdot}5 \times 10^{8\circ}K$ and for the D—T reaction is $3 \times 10^{7\circ}K$.

Even to approach such high temperatures for a demonstration that the threshold of one of these reactions has been reached is a major undertaking. One way, which has been described in the literature, is to employ the constrictive "pinch" effect exerted by the magnetic field encircling a pulsed gas discharge channel and thus by increasing the current density to effect a rise in temperature.

This simple pinching process can only be carried a certain way, for the gas pressure inside the constricted filament soon becomes comparable with the magnetic pressure outside it and the system begins to expand once more. British workers with circular discharges induced in glass toruses have shown also that even for the limited duration of a rapid "pinch" they are rendered inherently unstable by the development of "kinks" which grow to touch the walls of the tube and pass heat away to them.

It would appear from recent statements that the instabilities can be overcome.* A plasma at these temperatures indeed has properties which can be used to stabilize it. At 10^8K its thermal conductivity is a million times and its electrical conductivity 300 times that of copper. Even below these temperatures it responds readily to the control of electromagnetic forces arising from interaction of the conductor with specially arranged magnetic fields. It would seem that such a " magnetic bottle " can keep it in place.

This first step appears to have been successfully taken in that it has been announced that workers at Harwell led by Thonemann have obtained temperatures with the torus ZETA at which one of the reactions mentioned above produces a considerable number of neutrons. It has not yet been established with complete certainty that the neutrons observed do not arise from some subsidiary mechanism but work is proceeding to exclude such a possibility. In this field as in many others it is difficult to prove a complete negative.

Whatever has at present been accomplished in passing the threshold, it is clear that the problems to be solved before we can obtain useful power from this process are formidable compared with the first achievement of the reaction itself. The gas must be heated to extremely high temperatures long enough for at least a few per cent of the nuclei to fuse. This means containing a plasma in a tube at a temperature at least twice that of the interior of the sun (probably ten times) for a time of the order of a second, and repeating the process at frequent intervals.

It may take many years before useful and economic power is obtained in this way, but there seems little doubt that it will come. Mention has already been made in the literature of the possibility of making use of the magnetic properties of the hot plasma to induce electric power directly into an external coupled circuit and so get more electrical power directly out of the discharge than was put in to heat and control it. Mention has also been made of the use which might be made of the neutrons which are emitted as by-products of reactions (*a*) and (*c*). They obviously might be employed to breed fissile from fertile material or to produce tritium fuel from the reaction $n + Li^6 = He^4 + T^3$.

I must apologize for many omissions and inadequacies in this general picture of the work in physics which is going on at Harwell. But I think you will agree that it brings to mind the words of Francis Bacon in connection with natural philosophy in general : " A point invisible yesterday is its goal to-day and will be its starting point to-morrow."

* This lecture was delivered before the declassification of Zeta and other results.

Reviews of Books

TECHNIQUES OF MATHEMATICAL ANALYSIS

By C. J. Tranter

London : English Universities Press. Pp. xi + 396. Price 27s. 6d.

This book is a sequel to Dr. Tranter's *Advanced Level Pure Mathematics*. It might therefore be thought of as designed for the Open Scholarship candidates at the universities but quite rightly the author has not intended this. Much of the work of candidates for an Open Award is common to that of the first year university student of both the Honours Mathematical School and the General degree course, and the book is planned for these three kinds of mathematical specialist and will form a welcome addition to their text books. It will perhaps be more especially sought after by the candidates for Oxford and Cambridge Open Scholarships as there is much in the text and the examples (both worked and set) which they will find of particular value.

Beginning with Dedekind's theory the work then covers the parts of algebra, trigonometry and calculus usually considered necessary to give a sound introduction to mathematical analysis. Written in clear lucid style, the writer adopts the more sophisticated approach that would be expected from a text book devoted to the beginnings of analysis. In spite of this more sophisticated approach, explanation of the more elementary parts of the text are given quite fully where necessary and excellent use of diagrams is made, particularly in the chapter on complex numbers where the author deals very lucidly with transformation.

The printing, layout and general presentation are first class and the English Universities Press is to be congratulated on its good production of a most useful text book which most mathematicians at some time in their career will find of great value.

A. K. SMETHAM.

NEW INTERMEDIATE PHYSICS

By G. R. Noakes, F.Inst.P.

London : Macmillan & Co. Ltd. Pp. viii + 961. Price 30s.

This one-volume textbook of physics is most suitable for sixth-form school use, particularly for those preparing for the Advanced and Scholarship level examinations of the General Certificate of Education. Its title is not perhaps well chosen, for the Intermediate examination is no longer of importance and the inclusion of the word "New" in the title is inappropriate except maybe to indicate that the book has never appeared before in its present arrangement.

There are four parts to the volume and these incorporate under a single cover the substance of the author's earlier and well-known four separate textbooks on general physics, heat, light and electricity and magnetism. The first two parts, on general physics and heat, contain the somewhat condensed but otherwise unaltered text of the general physics and heat textbooks and are thus in some respects not up-to-date. For example, the 1927 International Temperature Scale is quoted in detail and no mention is made of the replacement of the ice-point by the triple point of water. To complete the plan of a single textbook of physics a chapter on acoustics has been added to the general physics section.

The text for the light and electricity sections has been completely rewritten and differs considerably from the original textbooks on these subjects. As far as possible the wave treatment is used in the light section, and both the "real is positive" and the "new Cartesian" sign conventions are employed in the discussions of lenses and mirrors. For comparison the alternative derivations are reproduced in full alongside each other. Because of lack of space the description of interesting phenomena and recent experimental methods is very often curtailed, as, for instance, the measurement of the velocity of light where the reader is referred to the author's *Textbook of Light* and to Essen's recent work (but without bibliographical reference). In the Electricity section the m.k.s. system is used throughout and the treatment follows the general lines of the Science Masters' Association Report on the "Teaching of Electricity." Both electrostatics and magnetostatics are given adequate treatment in addition to electromagnetism and some attempt is made to acquaint the student with the various modern types of magnetic materials and with semiconductors and semiconductor devices.

There is no doubt that the author knows and understands his subject and in addition has considerable experience of how best to present the fundamental principles to his readers in a straightforward and comprehensible way, but the textbook has one obvious shortcoming. Physics to-day covers a very wide field and therefore the author of a textbook of physics must be selective in the topics chosen to be dealt with in detail. However, Mr. Noakes has not been selective enough and in consequence he has been unable to make physics appear to be the attractive and vital subject it is. Surely it is most essential to make plain to the young student by reference to modern applications how important the knowledge of the fundamental principles of physics, and also trained physicists are to the present and future progress of industry.

It is often taken for granted that the textbook is always used in conjunction with adequate demonstrations of apparatus either in the classroom or laboratory and it is therefore superfluous to include illustrations of catalogue apparatus in the textbook. Mr. Noakes follows this practice, but he very wisely improves the clarity of his textual descriptions by numerous line drawings. It is a pity that they have been so reduced in reproduction that in far too many cases, particularly in the Light section, it is impossible to make out the details without using a magnifying glass.

The reviewer as a member of a university department of physics has, to his surprise, found on many occasions how very few university applicants have heard of Lord Rutherford. Perhaps this is not all the fault of the students for even this most admirable textbook which includes Mach and even Čerenkov in its text and index, makes no mention of either Bragg or Rutherford, or indeed of any of our own British physicists famous and well known to-day.

Schoolmasters will find the textbook most useful and economic. Their pupils too will like it, and given the stimulus of a good teacher and good laboratory facilities will thrive on it. For others the four separate textbooks are perhaps a better recommendation.

S. WEINTROUB.

The Annual Dinner

THE Institute's first Annual Dinner was held at the Savoy Hotel, London, on Wednesday, March 26. The attendance was 267, of whom 124 were members, 122 were ladies or other members' guests and 21 were official guests of the Institute. The official guests included the Rt. Hon. Viscount Hailsham, Q.C. (Lord President of the Council), Sir George Barnes (Principal, University College of North Staffordshire) and Lady Barnes, Sir Harry Melville (Secretary of the Department of Scientific and Industrial Research) and Lady Melville, Mr. H. McNeil (President, Institute of Fuel) and Mrs. McNeil, Dr. G. B. B. M. Sutherland (Director, National Physical Laboratory) and Mrs. Sutherland, Professor W. Wardlaw (President, Royal Institute of Chemistry) and Mrs. Wardlaw, Dr. D. C. Martin (Assistant Secretary, Royal Society) and Mrs. Martin, Mr. D. J. B. Copp (Secretary, Institute of Biology) and Mrs. Copp, and Dr. A. C. Stickland (Secretary, Physical Society). Past-Presidents who attended were Sir Lawrence Bragg, Dr. F. C. Toy and Sir John Cockcroft.

Lord Hailsham (left) *and the President.*

Members and guests were received by the President and Mrs. Humphreys.

Mrs. O. W. Humphreys.

The toast of The Institute of Physics was proposed by **Viscount Hailsham** in the following terms :

" It is related that that prominent ' egghead ' of the eighteenth century, Immanuel Kant, after considerable internal debate, at length decided to get married. When, however, he called at the young lady's house, he found, to his intense disappointment, that she had left the town twenty years before. Until to-day I have always regarded this as the most striking, and in some ways the most praiseworthy, example of the intellectual's preoccupation with the things of the mind. However, I learn to-day that your Society has actually been in existence forty years before holding this, its first, annual dinner. I do congratulate you ; in these days of constant dining out yours is an example of rare merit, and I am glad that you have reserved for me the privilege of being the first Lord President to wish you well. I hope, however, that now you have found your

way to the dining room it will not be another forty years before your second annual dinner.

It is, however, suitable for a Lord President of the Council to propose the health of your Institute. The role of Government in science is indispensable, and inevitably unsatisfactory : indispensable because without Government money much essential scientific work would remain undone—unsatisfactory because science is a subject beyond all else jealous of integrity which must pursue its courses without political interference. Thus the problems to which it gives rise are equally difficult whether under authoritarian or democratic regimes.

But the truth is that science has an uncomfortable way of dictating the shape of things to come, and, in my view at least, many of the most thorny problems of political life would be dealt with in a more wholesome and practical way if solved by the pragmatic sanctions of technical requirements than if pursued as a doctrinal issue by means of *a priori* argument. Very often, for instance, the mere size of a project determines the method by which it is inaugurated. One of the most thorny problems of our time is the relationship between the private enterprise and public service principles, and political parties, including my own, spend a very great deal of their polemical life defending or attacking theoretical positions which often bear very little relationship to the actual. The American economy, for instance, is widely, and I should say rightly, supposed to be more deeply rooted even than our own in the private enterprise principle. Yet when I was in the United States recently I was privileged to visit a huge dam which was in process of completion as part of the Tennessee Valley Authority's system of power stations. It was being financed on the public service principle because in essence it was too large to be created by private subscription. When complete it would inject into the local economy fresh springs of power which would fertilize and improve both public and private enterprise.

Or take an extraordinary engine developed at Geneva in your own realm of physics by a mysterious organization known as C.E.R.N. This is a machine approximately, I am told, the size of the Round Pond for the purpose of carrying out fundamental scientific research into the nature of the atom. Ordinarily, I should have said, fundamental scientific research is best not carried on by Government departments, but in universities, and if it is carried on by Governments, nothing, I should have said, could be worse than a consortium of Governments. But this is an enterprise the very size of which requires the use not merely of public monies, but of public monies from a number of European countries if it is to be done at all, and which is none the less necessary to be done if knowledge is to be extended beyond its present frontiers. Incidentally, its very inauguration is an example of the cross fertilization which can emerge from a partnership between the statesman and the scientist. The scientist devised the synchro-cyclotron. But when it is brought into being by political action it requires a new type of economic and political association which might conceivably, in the hands of a good political technician, have other and equally important applications in other spheres.

(From left to right) *Dr. G. B. B. M. Sutherland, Sir Lawrence Bragg, Mrs. Sutherland and Dr. F. C. Toy.*

This brings me to my main theme, the necessity for a close partnership between Government and science, a partnership in which, though individuals may cross the boundaries of one into the other, the separation of function between the partners is to be preserved by objectivity of approach.

Although scientific research is not perhaps the ideal sphere of action for Government, Government has in the past been one of its main patrons. It is a sad reflection that the main motivation of this was, and is, not the betterment of mankind, but, directly or indirectly, the stern competition of war, and military science. It is also a bittersweet

(From left to right) *Mr. H. McNeil, Lady Cockcroft, Sir John Cockcroft, Mrs. McNeil.*

reflection that the value to society of scientific research is nowhere better illustrated than by the fact that, though desire for military excellence may have originally provided the main motivation, very few even of the military inventions which have been produced by it have had no repercussions on the industrial and social worlds. Modern civil aviation, electronics and nuclear generation could hardly be at all where they are but for the two terrible wars through which we have passed, and this is precisely the fact which prompts the question where, if only the peoples of mankind could be induced to make the sacrifices for peace they willingly undergo from fear of defeat in war, in other words where, if the primary motivation of all research were the benefit of mankind, could we not expect to go ?

For this reason, I believe, no one, not the most parsimonious of our financial critics, need be afraid that either in fundamental or in applied research we, as a nation or as individuals, are in danger of spending too much. Indeed the latest advice I have received from the Advisory Council on Scientific Policy is in the contrary sense. But, by the like token, this does not mean that we need never be afraid that our money is being wasted. On the contrary there are dangers of waste in the very nature of research itself. There is a sense in which the very object of a research project is, by success in its own field of endeavour, to render itself unnecessary, and the questions of the selection of projects, and their continuance pose delicate and difficult problems for Ministers, economists and scientists alike. In this country we have hit upon the device of research councils : the Department of Scientific and Industrial Research, the Agricultural and Medical Research Councils, under a Minister, for the time being myself, who is held responsible if things go wrong, but who is not administratively equipped to intervene except by personal interest, influence and encouragement. In other words, in a very real sense, Government research in civilian matters is in the hands of scientists, which is where it should be, and

(From extreme left and clockwise) *Mr. G. Munday, Miss G. Meier-Faust, Mr. W. E. Schall, Mrs. Schall, Mr. F. Y. Poynton, Mrs. Poynton, Mr. G. Parr (behind Mr. Allard), Mrs. Parr, Mr. L. S. Allard, Mrs. Allard, Dr. D. H. Follett, Mrs. Follett.*

Government responsibility is largely discharged by patronage (in the old and good sense of the word) and by interest, co-ordination, and, to some extent, as I should like to think, by initiative, vision, enterprise and encouragement.

Manpower and project selection are at the heart of good research. Research requires a constant influx of young and active minds. Research institutions should never become monasteries where the divine office is recited unceasingly for centuries. But the corollary of this is that the research worker should have prospects beyond his relatively short life as a researcher which render egress from the profession as attractive as entry. This means that teaching, industry, and administration should all co-operate in making the prospects of those with research experience as attractive as possible. It also means in part that civil research should normally be carried on by, or on behalf of, bodies primarily engaged in other activities, such as universities, teaching hospitals, industry or industrially sponsored research associations and that where it is not (which is normally the case in those branches of research for which I am departmentally responsible) there should be constant cross fertilization between the research institutions and user and teaching bodies.

Sir George and Lady Barnes (on the left) *with the President and Mrs. Humphreys.*

I believe on the whole we have achieved the right balance. Government finance cannot be dispensed with if research is to receive the support it requires, and if the public interest is to be formally represented as it should be. Direct political control and supervision is to be avoided if research is to preserve its integrity and science its independence. The latest figures show that this nation has been spending £300 million annually or rather less than 2 per cent of its gross national product on research. Of this £300 millions about £225 millions or just three-quarters is provided in one form or another by Government. I will not enter into the thorny question whether the Government contribution is adequate, or I shall have the Chancellor of the Exchequer on my trail. What I am quite certain of is that, viewing scientific research simply as an investment, the industrial and private contribution could with advantage be largely increased, and what I am also certain of is that Government Departments, economists, private industrialists and financiers all pay too little attention to the results of research when these are published and point to known and concrete conclusions.

I have probably said too much—from more points of view than one—but I will end by making two points. Successive Governments have encouraged industrial research by research associations, the object of which is the formation of a partnership in applied research between industrialists, scientists and Government, in which it is hoped that industrialists will take an increasing interest, and in which I would like to appeal to industrialists to encourage and promote the co-operation, which I know will be willingly given, of the Trade Unions. Fundamental research in the universities is also supported by Government in partnership with the teaching profession and the scientist.

But of one thing I am quite certain. Whatever the future of research in this country one can only welcome the emergence and efflorescence of professional bodies like The Institute of Physics. I am not sure that I would ever wish it to become a pressure group, although no doubt these bodies perform a useful function in a free society. But the organization of professional physicists into a self-conscious and articulate body is something which can only be welcomed by those who have the interests of science and the standing of scientists in this complex society of ours at heart. Now that you have achieved the natural corollary of corporate existence in the institution of an annual dinner it gives me great pleasure both personally and as a Minister of the Crown to propose its health. May it flourish root and branch and may

its annual dinner take place every year in future, and for a great many years to come."

Replying to the toast, **The President** said :

" This is an important occasion, the first Annual Dinner of The Institute of Physics, and we are very much indebted to you, Lord Hailsham, for giving us such a good send off. I must not steal Sir John Cockcroft's thunder, so will leave him to thank you more fully.

This is the second time that I have addressed members of this Institute as their President. At Oxford I was—quite deliberately—provocative. So for this evening I sought a topic dangerous neither to blood-pressure nor digestion. Finding such a topic was another matter. Indeed, judging by our daily papers, areas of agreement—national or international—are few and far between.

Nation argues with nation concerning the best route to the summit. Pineau dislikes Dulles's attitude about Algeria. Others just dislike Dulles. Britain and America find China a dangerous topic. No one loves us in Cyprus. Who can predict the future of the Middle East?

At home, Conservatives quarrel with Conservatives about economics : Socialists with Socialists about defence. Conservatives and Socialists just quarrel. Employers and workers disagree on the approach to the problem of inflation. Trade Union quarrels with Trade Union as to who shall drill which holes, where. Any day I expect to hear that the dockers are on strike because they dislike handling meat on Friday, or that Lord Hailsham is in trouble with the Union of Campanologists. University students assault and insult their Rectors, giving rise to nostalgic memories of the corrective influence of corporal punishment.

What a world ! We behave like children and complain that the rewards of maturity escape us.

But there is one thing on which I know we will all agree—that we live in exciting times, and especially so in the realms of science and engineering.

Consider for a moment just a few recent happenings. Artificial satellites circle the earth in increasing numbers. Jodrell Bank having proved its mammoth radio-telescope on Sputnik I now probes events far distant, both in time and space, receiving signals which started on their journey one hundred million years or more ago, when the world was more primitive, but perhaps not much more barbaric, than it is to-day. Harwell peers into the—we hope—less distant future and predicts the time when sea water will become a source of power, thus giving the old-fashioned voyager, storm-tossed in an old-fashioned ship, the consolation of knowing at last the purpose of the ocean.

Sir Harry and Lady Melville.

The more modern traveller foresees the time when his aeroplane will reach New York before leaving London—but presumably he will not be able to come back and decide not to start ! Chemists wrest the secrets of heredity from the chemistry of nucleic acid and prove that even women's beauty is merely a matter of chemistry—pure and applied. Telephone cables span the Atlantic. Semi-conductors open up new vistas to electronic engineers, and the digital computer rolls the hours into seconds. Fuchs makes history by crossing Antarctica in his Sno-cats, thereby stealing the American headlines from the news of Eisenhower's peregrinations round the golf course in his go-cart. Our standard of living becomes so high that wives have to go to work to enable their husbands to enjoy it.

Exciting ? Of course it is. You may not like it. You may long for the days of the hansom cab and the slow boat to China, but exciting it is beyond a doubt. Exciting to the scientist, the metallurgist and the engineer, as their interests continually merge more closely. Exciting to the industrialist, called upon to exercise his judgement concerning the investment of vast sums of money in unfamiliar areas. Exciting to the workman who wonders—but need not fear—what lies in store for him with automation knocking at his

(From left to right) *Dr. J. V. Dunworth, Professor S. H. Piper, Mrs. N. Clarke, and Miss J. E. Clarke.*

door. Exciting also to the teacher in school and university on whose adaptability and skill the future so much depends.

Exciting—yes—challenging also if, as a country and a profession we are to hold our own in face of the quickening *tempo* of scientific discovery and technological advancement. As a country we look back on past achievements with pride and satisfaction. But we can no longer rest on the prowess of a few great men. We have entered an era in which success demands the deployment of vast human resources. Have we those resources ? If so, are we using them to best effect ? Neither the shortage of scientists nor the establishment of committees to consider how to fill the gap is any longer news. Action, expecially action directed at improving quality as well as quantity, would be news—vital and inspiring news whose absence clouds our vision of the future with apprehension.

An outstanding quality of the British is their ability to improvise. True to tradition—faced with a shortage of scientists—we seek to recruit them from the ranks of would be historians—swords into ploughshares—a worthy operation, but who would start with a sword with a piece of virgin " plough-share " steel lying just to hand ?

Where are we most likely to find good " scientist-material " ? Surely amongst the families of men themselves trained to like professions. Yet, in our foolishness, it is to these young men that we make our universities most difficult to access, taxing their fathers to provide for others the help denied to their own children.

Only an enlightened Government can fully solve this problem. In the meantime, industry tries to fill the gap by providing advanced education for some of those denied it by the Welfare State. The problem is too big for industry alone. Last year at my own laboratories we had 16 applications for every opening for students for training—at our expense—either through sandwich courses or as full-time students at residential universities. Do not think that these young men were the rejects of the universities. Our sights were set high : any university would have been glad to number them amongst their undergraduates. Out of 19 day-release students who took their finals last year, only two failed. Which university can match this record ? Clearly the material is very good.

Maybe the problem is recognized but the solution deferred until our economic situation is a little sounder. Would one deny food to a starving man until he had put on a little weight ? The patient is ill—maybe acutely sc—and we are the patient. It may take time to determine a cure, but should we be denied the first-aid that lies immediately to hand ? Maybe we shall prove so resilient that nothing more is needed. You, Lord Hailsham, have a special responsibility for the scientific well-being of our country. Can you not bring your well-known powers of persuasion to bear on the Chancellor of the Exchequer ? After all, we only need 2 to 3 per cent of the £19,000,000 his successor has wrung out of Sir James Turner to put us on our feet. Could it be that to remove the means test would be regarded as politically inexpedient ? Surely it would be much more so to hand over a corpse to your successors.

So much for the nation. What about our profession ? I recently passed an idle hour dipping into John Steinbeck's delightful fantasia *The Short Reign of Pippen IV*. He enlivens his light-hearted discussion of French politics by enumerating the parties which comprise its parliament as follows :—

The Conservative Radicals
The Radical Conservatives
The Royalists
The Right Centrists
The Left Centrists
The Christian Atheists
The Christian Christians
The Christian Communists
The Proto Communists
The Neo Communists
The Socialists
The Communists

the Communists being themselves divided into

Stalinists
Trotskyists
Kruschevniks
Bulganinians

Splinter groups : each subordinating national welfare to its own sectional interests with near-disastrous results to the stability of French Government.

Is there here perhaps just a glimmering of a warning for us ? Splinter groups : science subordinated to technology.

Do not misunderstand me. We need technologists. Doubtless, many will find lasting satisfaction in the mastery of one technology. But are there, perhaps, others who would have enjoyed the pursuit of scientific knowledge on a broader front, who become trapped in a technology ? Or still others whose broadening interests might have taken them beyond the boundaries of science —narrowly defined—who find themselves deprived of the experience which the new ventures would demand ?

If it be true that too many physicists become the victims of over-specialization, what should we do about it ; we who have the great responsibility of guiding the younger members of our profession ? First we must decide what it is that we wish to achieve. Surely it is to provide young scientists with the education and training that will so develop their latent abilities that they may live the fullest possible lives, to their own benefit and to that of the community. To achieve this, education and early training must progress on a broad front, developing the whole man—not just the scientist—still less the narrow specialist.

The first object of the university should be to provide graduates with a plateau of knowledge in the chosen science, devoid of major peaks : bounded not by precipitous cliffs but sloping off into neighbouring sciences and with spurs projecting into territories well outside the realm of science.

After graduation is soon enough for specialization—the first exploration of a peak. But the learner should not be allowed to stay too long on his first peak ; he should be encouraged to try several peaks, maybe in close proximity, maybe in different regions, in order to achieve a familiarity with them which in later years will ensure mobility, or, should his interests and ambitions lead him eventually to attack a peak not previously explored, to do so with the advantage of a thorough knowledge of the terrain from which the peak emerges.

This freedom is more easily secured in the university than in industry. Industry must learn that the quick dividends to be derived from early over-specialization by young graduates may be very dearly earned. If we would safeguard the future, we must allow our young men to achieve breadth in their scientific pursuits ; we must also give them the opportunity to see something of the world outside the laboratory. To gain some

Professor and Mrs. E. C. Stoner.

insight into the problems of production, of commerce and of education, and to meet men working these fields, which, in later years, they themselves may wish to enter.

The third influence to which the young physicist is exposed—and it must not be under-rated—is that of the family. Ladies—while your menfolk ponder whether I am getting at them—which I am not—or genuinely seeking their collaboration in dealing with our younger colleagues—which I am—let us have a little *tête-a-tête*.

Do you like concerts ? The theatre ? Do you like a little social life ? Do you prefer not to take your pleasures too scientifically ? Do you even like occasionally to talk to your husbands in the evenings instead of watching television or knitting, while they work ? You do ? Maybe you have suffered too long in silence—but you could warn

the wives of your husband's younger colleagues—encouraging them to see that family life has a fair chance—that the development of the man keeps pace with that of the scientist to the undoubted benefit of their husbands' health and the probable advancement of their careers. Your power is very great ; make good use of it.

And so, Lord Hailsham, if you and your colleagues in Government will see that the material—the very good material—we know to exist is made available, we—the universities and Industry, ably supported by the ladies—promise that we will so shape and fashion it that our country—small in size but big in heart—will maintain that proud tradition of scientific leadership which is its fair and proper heritage."

Sir John Cockcroft proposed the toast of The Guests :

" I am very glad to have the opportunity of proposing the toast of the guests on the occasion of the first Annual Dinner of the Institute.

First of all, of course, I must say something about our guest of honour, Lord Hailsham, the Lord President of the Council. The office of the Lord President is a very ancient one and goes back, I believe, to the sixteenth century. At that time he was a very important administrative officer of the Crown, and no doubt spent a lot of time chopping off the heads of his political opponents. To-day he hasn't that privilege and I am sure we would all agree that his most important function to-day, amongst his many functions, is that of taking care of the D.S.I.R., the Agricultural Research Council and the Medical Research Council. He is not a Minister of Science and I am sure that he would not wish to be a Minister of Science. He doesn't wish to administer these departments in detail but at least he is a benevolent patron of science, answering for their misdeeds in the Upper House, and no doubt trying from time to time to screw some more money out of the reluctant Treasury. In carrying out these duties he does, of course, have to understand the language of science. He must know the difference between reps and rems, he must know what sunshine units are, he must know the difference between antiprotons and antineutrons, and mesons and hyperons and barytrons, otherwise he wouldn't know why we are spending all this money ! But all of this, of course, comes naturally to him since part, at least, of his genetical make-up comes from the Quintin Hogg who founded the Regent Street Polytechnic. As a past scholar of Christ Church, a Fellow of All Souls, and Minister of Education, he must, I think, believe that our strength in the future, as in the past, comes from our stock of really well educated men, whether humanists or scientists, and would no doubt agree that some modest increase in the proportion of scientists is necessary for the world of to-day.

Another important body of our guests is our ladies, and I am sure that all Members of the Institute present to-night will be very glad that the Board has adopted the civilized practice of inviting them to this Annual Dinner to diversify and adorn this occasion.

And then I must mention the Presidents and Secretaries of our fellow Institutions. In the past the Presidents of our Institute have enjoyed the hospitality of our fellow Institutes and it is a pleasure to be able to return, for the first time, their hospitality. Presidents and Secretaries of Institutes are one of the over-worked classes. Some of them are at present touring the Antipodes (no doubt they would be here to-night if they were not) no doubt making two or three speeches a day—eating large lunches and dinners—a well-known method of getting rid of our seniors. We have this in common with our fellow Institutions, that we are interested in promoting the development of science and technology in this country especially by the training of our younger members.

We have also amongst our guests the Director of the National Physical Laboratory, Dr. Sutherland, an old friend of many of us. Dr. Sutherland is the latest of a long line of distinguished Directors of the N.P.L., starting with Glazebrook in the early years of the century. We have with us Sir Lawrence Bragg, another Director of this great Institution. No doubt like every new Director, Dr. Sutherland has got his own ideas as to how to revamp the programme and character of the N.P.L.

And then we have with us Sir Harry Melville, who a year or so ago took over the job of being Secretary of the D.S.I.R. Many of us present to-night have been very grateful in the past for those modest maintenance grants which kept us on the bread line, but at any rate did allow us to pursue research—though nothing else besides research. I also had a few modest grants—the largest, I think, in the whole of the D.S.I.R. existence was for a long period of time one of two or three thousand pounds to the Cavendish Laboratory in the late 1920's and I am sure that was thought to be a great extravagance. But now, of course, Sir Harry Melville thinks nothing of making grants of a hundred times this sum to a really deserving cause. And as you all know, the D.S.I.R. has been given a new constitution and an invitation to develop a new look, and Sir Harry

Melville has the onerous responsibility of leading the D.S.I.R. in this direction. And I am sure that with his training as a University professor, he will do this very well indeed.

Well then, finally I come to Sir George Barnes with whom this toast is coupled. He is very well known to us for his work as Director of Television for the B.B.C. Television is, of course, a very important means of communication in the world. It contributes to the growth and decline of politicians as the Lord President well knows. It is beginning to play an important part in the education of the young ; I believe there are 12,000 T.V. sets in the schools, no doubt encouraged by Lord Hailsham in a previous incarnation, and I hope that some of Sir Lawrence Bragg's very elegant lectures will be distributed to wider audiences in the future by this means. Television is also contributing to the decline of national institutions, such as cinemas and pubs, and in the U.S. is encouraging new forms of abnormality known, I believe, as " telly-legs." For all of this Sir George Barnes is, in part at least, responsible. However, he has recently turned over a new leaf and has become Principal of the University College in North Staffordshire, and in this he is taking part in a great new educational experiment. One of the Presidents of Magdalen was interviewing a candidate for entrance to the College, to read history. He said,

" Well, why didn't you want to read classics ? "

" Oh, Sir, classics is very difficult."

" Why didn't you want to read science ? "

" Oh, Sir, scientists are so ignorant ! "

I am sure that Sir George Barnes, together with our Honorary Secretary, Professor Vick, will play a large part in making sure that some, at least, of the scientists of the future are not as ignorant as the scientists of the past. And now I would ask you to rise and drink the health of our guests, coupled with the name of Sir George Barnes."

On behalf of the guests, **Sir George Barnes** replied as follows :

" My first pleasure to-night is to thank Sir John Cockcroft and all members of The Institute of Physics on behalf of all my fellow guests for the excellent way in which they have carried out this excellent intention of theirs of having an annual dinner. We are honoured by your invitation and in being here to-night, and we have thoroughly enjoyed ourselves—up to this moment !

It is said that when a friend once pointed out to an absent-minded physicist, who was returning from the Cavendish Laboratory to Trinity College, Cambridge, that he was wearing one brown shoe and one black, he replied with glee, " You see, I have another pair exactly the same in my cupboard." Now at Keele, in the University College of North Staffordshire, no student wears a like pair of shoes, because everyone has to read two subjects and although the majority of physicists there choose to read, as their second subject, something analagous, such as mathematics, chemistry or geology, a few bold ones are prepared to put a different coloured shoe on the other foot and to read conjointly with physics a humanities subject. We welcome at Keele Sir George Thomson's heartfelt aside in the discussion at Cambridge on the proposed new tripos when he said " let our teaching also be founded on experiment."

Dr. and Mrs. K. A. G. Mendelssohn.

At Keele, we study our subjects in parallel and not in series, and it is our aim to provide professional competence—in both of them. So, to do so, we confront what, to my mind, is the most painful task of the educationalist to-day, and that is to discard—to know what to eliminate in face of the increasing bulk of knowledge—from his own precious syllabus. Secondly, because we are dedicated to joint honours we must establish connections between subjects not only on the surface, but at different depths beneath it. Now, one of the links between any two groups of disciplines is language, and this use of language for exact expression and thinking is something, I

Mr. and Mrs. A. J. Garratt.

believe, which the scientist needs. However skilled you gentlemen may be in thinking mathematically, or in expressing your thought with the designer's pencil you do need an exact use of words as well. We have it on the authority of Mr. Ratcliffe that physical phenomena are best and most fruitfully described in words. And I believe that the humane studies can be of great use to you here. I am quite certain that the proper and exact use of language is one part of education which at all costs we must not discard. Another way, I think, in which an Arts discipline can assist the scientist to think critically about his own activities, is the study of the philosophy of science and we, at Keele, have made that subject, allied with logic, one of our most fruitful subsidiary courses.

But the more urgent and the more difficult task —and to me by far the more interesting task, is how to convey some understanding—some glimmering of science to those who are not going to make science their profession. We are all familiar, I expect, with the Cambridge proposals and to the solution in them which has been so happily presented by Mr. Ratcliffe, and which—as I remember at your meeting last summer at Oxford —Mr. Alan Bullock transferred to the needs of an even older University—into terms which would suit Oxford.

Well, Keele is committed to making the attempt as part of its ordinary curriculum, and our experience, as would be expected, is that the only way to do it is to depend on the teacher. The presentation of science, or as Cambridge still prefers to call it, "a science," to the amateur requires for success that the teacher must himself possess the curiosity to explore the alien discipline and himself be convinced of the worthwhileness of the labour needed to acquire it. It can only come from those who have made the effort and found it rewarding and amongst those, may I say that we are very proud to have at Keele your Honorary Secretary and our Professor Arthur Vick.

Now my long experience in the B.B.C., most of it on what is known as the Talks side, convinced me that too few scientists are interested in the diffusion of their special knowledge. The popularization of science, through broadcasting or through the newspapers, hasn't always succeeded, and where it has been most successful, it has not always attracted the approval of the learned. Science in this country is not yet, as apparently it is in Russia, a part of the common culture. I have followed very carefully the three previous speeches and the only two scientific metaphors which have been used this evening were both used by myself, "contact" and "in series and in parallel." I think that only the arousing of unending curiosity about science in the general public is going to make it part of the common culture. Too often enthusiasm is sealed off at school by dull teaching or is withered later in life by the sarcasm of the narrowly arrogant and the ridicule of the ignorant and the smug. Popularization may have no place in an Honours degree—we were reminded of that more than once in the discussion at Cambridge —but it has a very important place in a democratic society. If the pyramid of scientific endeavour is to reach upward towards Heaven, it's base must be much broader than the male science specialist in school and university. That base, to my mind, must be narrower in an educated democracy than the people themselves. Scientists in this country are too thin on the ground. Your President has said so, and I am quite convinced that it is true. The intake is not nearly fast enough to balance the outflow. The drain on the reservoir of ability is much too great at the moment. Now, in scientific pursuits generally, and in industry in particular, it seems to me that we endanger the future of our economy by our disinclination to employ women graduates on the same terms as men. I am not talking about equal pay. That battle has been fought. Our grandmothers won the right to higher education, but still every article and every speech about education reveals that the thinking

behind it is in terms of boys and men. And still the teaching of mathematics and science in girls' schools falters and the spark is practically never struck. Yet if scientific man-power is needed, as your President has stated, how can any nation afford to recruit it from only half its number ? Of course I understand the reluctance of the employer to train someone who will shortly get married and, as *they* say, be lost for ever. And I suppose among scientists that is true because when after—and it is now only fifteen years—the child-bearing, child-rearing age the woman is once again employable, she has lost touch with science because you push it ahead so fast. I must say that I've been struck, since I went to Keele, by the, often serious, psychological difficulties created for the student by the lack of sympathy in his home—the lack of sympathy with a child's intellectual interests, particularly from the mother. Now that has nothing whatever to do with science, but we, as educationalists, are concerned with the next generation, and it is essential in my opinion to provide some sort of education in which a knowledge of science should not be excluded from the mothers of that generation.

Well, I leave you, ladies and gentlemen, with a controversial point. Whichever shoes we may wear—brown or black—on our way back from the Cavendish Laboratory—and possibly some of us will wear both, let us—physicists and humanists —adopt the motto of Walter Savage Landor and enjoy to warm our hands, both hands, before the fire of life."

Correspondence

M.K.S. Units in physics teaching

If all those who have contributed in print to the discussion about m.k.s. units and the teaching of electricity were to form their own luncheon club, they might well choose as its motto *Quot homines tot sententiae*—were it not that this might be regarded as provocation by those who would rather abandon the classical approach !

In the Edinburgh University physics department we decided, after long hesitation and with some qualms, to adopt the m.k.s. system, and on the whole we are satisfied that this was right. We are however convinced that our task will be made more difficult, rather than easier, if the Scottish schools do the same. It seems to us that a thorough grounding in the classical units systems, in electrostatics, magnetostatics and the current/potential relationships in simple circuits, is a valuable introduction to the study of electricity and magnetism. We only wish the Scottish Education Department—which wields power undreamed of in England—would realize this.

I agree therefore with Mr. Macfadyen's plea [1] that the schools—at any rate, the senior secondary schools—should for the time being adhere to—or revert to—a more or less logical development of the fundamentals of electricity and magnetism along the historical route, introducing practical units frankly for the sake of convenience. The first university year is then a convenient stage at which to give a " conversion course."

However, Macfadyen's condemnation of the m.k.s. system seems to me too sweeping and this " conversion course " can be given rather more logic and coherence than he seems to suggest.

One of Macfadyen's major points is his criticism of " the divorcement of D from E and B from H in free space." The only system of units in which D and B are dimensionally identical with E and H respectively in free space is the Gaussian system, in which these identities are secured through the introduction of a quantity with dimensions L^2T^{-2} and magnitude 9×10^{20}. Either we carry this with us for two years as another tiresome conversion factor or we write it as c^2 and throw away " the almost miraculous revelation of the inner meaning of the prosaic units ratio." But really the miraculous revelation is that there are electromagnetic waves with the same speed as light waves ; this revelation will come in any case, and if our students read *Science News* they will take it for granted long before we get round to telling them.

In either e.s.u. or e.m.u., then, we cannot have *both* B and H *and* D and E identical ; should we then expect both pairs to be identical, or one pair (and if so which ?) or neither ? Macfadyen appears to answer " Both," and therefore to call for Gaussian units, in his statement :

> " The original and proper function of flux-density is to represent the combined effects of a polarizing field and a polarized medium, as the equations
>
> $$B = H + 4\pi J$$
> $$D = E + 4\pi P$$
>
> indicate."

This was indeed their "original" function, but is it to-day their "proper" one? What is the proper function of any symbol, or hypothesis? This is not a question of fact, but an opening for endless—and fruitless—argument. Surely then the juxtaposition of "original" and "proper" is misleading.

Operational definitions of D and E, such as those given by Goodier[2], lead us to expect them to have the units of coulombs per square meter and volts per meter respectively; the reasons for the occurrence of these units are clear from the defining experiments, and the interpretation of D as the displacement density and of $\dot{D}$ as displacement current is readily understood and is historically honourable. The identity in e.s.u. of D and E in vacuum then appears as a trick, rather than as something fundamental. B is defined, straightforwardly, from flux and the phenomenon of electromagnetic induction. H turns out to be the most nebulous of the field quantities, for there is no experiment which leads naturally to a definition of H. As Goodier points out "there is no way of measuring H save with an ammeter and a meter ruler," and this is not in any sense a measurement of a field quantity. There is therefore a considerable arbitrariness about the definition of H, and it is reasonable to define H in the way which gives an agreeable symmetry in the mathematics, so that H and B have a relationship similar to that of E and D. It does not seem that we are bound to expect B and H, D and E to be identical in pairs, in a vacuum or anywhere else, and the "divorce of the flux densities from the field strengths"[1] may be a legitimate termination of a marriage of convenience.

It is true, as Wallace said,[3] that there is a great deal of "obscurity and lack of logic" in many of the books and articles which advocate the adoption of this or that "m.k.s. system"—for instance in the S.M.A. report.[4] Many of these obscurities are certainly not inherent in the system, but arise now because many of us were not clear enough about what we were doing in the "old system." Until our own minds are clearer there will be a good deal of room for debate about the most suitable teaching sequence. At their various levels books such as those by Stratton, Bleaney and Bleaney, Cullwick, and Mackenzie[5] are notable contributions to this debate. For some time to come, though—perhaps until the post-prandial rumblings of the m.k.s. luncheon club have died away—the precipitate adoption of new sequences in the schools, for the sake of fashion, may bring little gain and much loss.

R. M. Sillitto (*Fellow*).
University of Edinburgh.

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4. "The teaching of electricity." Report of the Science Masters' Association (Murray).
5. Stratton, J. A. *Electromagnetic Theory* (McGraw Hill).
   Bleaney and Bleaney. *Electricity and Magnetism* (Oxford).
   Cullwick, E. G. *The fundamentals of electromagnetism* (Cambridge).
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If you would care to extend a little further the discussions on electrical units which have been such an interesting feature of recent issues of the *Bulletin*, I should like to offer a comment on the article in the February issue by my friend Mr. Macfadyen. After practising the science of electricity for many years, during which I utterly eschewed the m.k.s. system, I found myself, as a university teacher, having to face the formidable problem of exposition. My experience was the reverse of Mr. Macfadyen's: after earnest consideration I felt that the c.g.s. system was essentially unteachable. My two main difficulties were the mixing of electrical and mechanical units in the force laws and the basic phenomenon that fields cannot be established instantaneously.

I attempted in my teaching to avoid a deliberate choice between two sets of units. By writing the force laws as $F = \lambda q_1 q_2/r^2$ (electric charges), $F = \xi m_1 m_2/r^2$ (magnetic charges), and introducing a numerical factor ζ to relate the potentials produced by a magnetic shell and a current loop, we can show that[1]

(i) there are vectors $(\zeta/\lambda)\mathbf{E}$ and $(\zeta/\xi)\mathbf{H}$ derivable from the field vectors $\mathbf{E}$ and $\mathbf{H}$;

(ii) the circuital laws take the forms

$$\int \mathbf{E}.\mathbf{ds} = -\int\int \frac{\zeta}{\xi} \mathbf{H}.\mathbf{dS} \text{ and } \int \mathbf{H}.\mathbf{ds} = \int\int \frac{\zeta}{\lambda} \mathbf{E}.\mathbf{dS}$$

(iii) $(\lambda\xi)$ has the dimensions of velocity squared;

(iv) fields are propagated with a velocity $\sqrt{(\lambda\xi)/\zeta}$

With regard to (iv) it is possible to give a demonstration based on the elementary form of the laws which establishes both velocity and the direction of the vectors. (I think Mr. Macfadyen is a little unfair in suggesting that the velocity of light gets into the m.k.s. system in disguise !) We can then show how λ, ξ and ζ are chosen in the main systems of units.

The choice between the systems of units is, I think, the choice between two slightly different models of the electrical universe. Provided these models are self consistent and present the basic equations in a concise form, the differences cannot have much fundamental significance. It is certain that we cannot escape the difficult philosophical implications of our subject by opting for a particular set of units.

I was charmed by the coalman so felicitously introduced by Mr. Macfadyen. Working under m.k.s. authority, he has at least recognized a relationship between mass and weight : under c.g.s. authority he might find himself buying in hundredweights and selling in microgrammes !

N. F. Astbury (*Fellow*).
The British Ceramic Research
Association, Stoke-on-Trent.

REFERENCE

1. *Introduction to Electrical Applied Physics.* London: Chapman & Hall (1956).

Mr. K. A. Macfadyen comments :

It should be remembered that my article was concerned with the *elementary* teaching of students intending to proceed to the higher branches of the subject. Particular stress was laid on the importance of clear concepts, simple definitions and logical argument. Dr. Astbury would not, I am sure, claim that his book was suitable for beginners.

Women in Science and Technology

A Working Party on Women in Science and Technology has been set up by the British Federation of University Women to study the part women can play in the present-time shortage of trained people. We felt that we should look first to the schools and, realizing the lack of readily accessible information about careers, we published a booklet, *Opportunities for Women and Girls in Science and Technology*, intended for the use of school-girls and their teachers and parents.

This pamphlet was received with enthusiasm and the first edition was quickly sold out. Great interest has been shown in this problem throughout the country and it has formed the topic of many meetings and discussions. There is now a steady demand from education authorities, schools, parent-teacher associations and other organizations for speakers on this subject, both from the point of view of practical opportunities available and of the educational problems involved, and we are now forming a panel of speakers, mainly of women scientists, who would address such meetings.

We should be very glad to hear from any members of the Institute who would be willing and able to talk to these kinds of audience. We hope to find a sufficiently large number of speakers so that the demand on any one person would be small. Expenses are met by the organization requiring the speaker.

Constance E. Arregger (*Fellow*),
Leader of the Working Party on Women in Science and Technology.
British Federation of University
Women Ltd.,
17a Kings Road,
London, S.W.3.

Forthcoming Institute Meetings

May 30 North Eastern Branch At King's College, Newcastle upon Tyne, 5.45 p.m. Tea 5.30 p.m.
Branch Annual General Meeting
followed at 6.15 p.m. by
" Exploration of the Structure of Solids by Magnetic Resonance "
DR. E. E. SCHNEIDER, F.Inst.P.
(*King's College, Newcastle upon Tyne*)

May 30 Electron Microscopy Group At the Arts School Theatre, Benet Street, Cambridge.
Joint Meeting with the
Scientific and Technical Group of the Royal Photographic Society
" Photographic Aspects of Electron Microscopy "
(Further details are available from the Institute)

June 7 London and Home Counties Branch Summer Meeting
Visit to Marchwood Power Station and the New Forest
(Further details are available from the Institute)

June 16-20 Non-Destructive Testing Group Joint Meeting with the Société Française de Metallurgie
" The Utilization of Physical Properties for studying the Relationship between the Constitution, Structure and Service Behaviour of Metals "
(Further details are available from the Institute)

June 19-20 Applied Spectroscopy Group At Cambridge.
Summer Meeting and Group Dinner
Visit to Cavendish Laboratory and the Radio Telescope
(Further details are available from the Institute)

The Institute's Journals

PRINCIPAL CONTENTS OF THE MAY, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 5

ORIGINAL CONTRIBUTIONS

Studies in microdensitometry. By W. A. Wooster, F.Inst.P., and J. A. L. Fasham.

A discussion is given of some factors which affect all microdensitometer studies on X-ray photographs. The particular problems which affect powder photographs, preferred orientation photographs, single crystal photographs and diffuse reflexion photographs are then considered. The use of a rotating circular stage for the investigation of rings of varying density and the use of an integrating mechanism for the determination of the integrated reflexion in a line or spot are described.

The Construction and testing of a " universal " light scattering apparatus. By W. J. Hughes and P. Johnson.

The construction and testing of a light scattering apparatus, suitable for the investigation of macromolecules in solution has been described. By the use of a parallel beam of light through the scattering solution, calibration anomalies have been removed and the apparatus can be calibrated by, or utilized for scattering measurements on, liquids of any refractive index.

A compensated moving cylinder viscometer. By G. M. Sreekantath, and C. A. Verghese.

Based on the principle of Lawaczeck's falling cylinder viscometer, a new viscometer has been designed, in which the only measurement to be made is the time taken by the cylinder to move a definite distance, without the necessity of either observing the movement of the cylinder or measuring the densities of the cylinder and of the liquid. The instrument consists o two exactly similar light solid cylinders or cylindrical bulbs moving in similar vertical tubes of slightly larger diameters containing the liquid at the same temperature. The ends of each cylinder are made conical to ensure its coaxial movement in the tube and the cylinders are attached to the ends of a Nylon fibre which passes over a light frictionless pulley. Attached to the same fibre at suitable heights above the cylinders are two similar lightweight carriers on either of which riders of equal mass may be placed. When a certain number of riders are placed on one side, the cylinder on that side moves down while the other cylinder moves up with uniform speed, the pulley turning round once in a time T which is directly proportional to the viscosity of the liquid. This result may be used to compare the viscosities η_1 and η_2 of two liquids using the same number of riders and noting the times T_1 and T_2 respectively for a complete rotation o the pulley. $\eta_1/\eta_2 = T_1/T_2$.
The instrument is capable of high accuracy and has the special feature that a knowledge of the density of the liquid is not needed in the calculation of the result.

A double d.c. bridge circuit for precision measurements with load cells. By T. S. Parramore.

By arranging the strain gauges on a load cell as a closed bridge which is wired in parallel with a similar reference bridge in the measuring instrument, a very sensitive and accurate manually balanced null deflection method of measuring the output of a load cell can be achieved at low cost. This method is also suggested as an alternative to the present d.c. methods used for load cell measurement in the calibration of testing machines.
The prototype bridge has a discrimination of one part in 10 000. A practical difficulty when used with load cells greater than 50 tons caacity is to calibrate against a standard of sufficiently high accuracy.

Derivative mass spectrometry. By J. H. Beynon, A.Inst.P., S. Clough and A. E. Williams, Grad.Inst.P.

Double differentiation of the ion beam in a mass spectrometer is shown to have the same effect on peak shape as reduction to zero width of the inlet and exit slits. When this differentiation is performed by modulation of the accelerating voltage, increase of the modulating amplitude results in effective control of the width of both inlet and exit slits making the spectrometer more versatile since its sensitivity and resolving power are easily controlled. Differentiation by an odd number of times enables the centre of a singlet peak to be located with greater speed and accuracy, thus improving the mass measurements made with the spectrometer.

An electronic feedback seismograph. By M. J. Tucker, A.Inst.P.

The seismograph described has a nearly uniform response to ground oscillations whose periods lie between 1·5 s and 12 s, which is the range of particular interest for research on microseisms generated by sea waves. The seismograph consists of a 1 s pendulum which measures ground acceleration over the range of frequencies of interest, and an electronic circuit performing double integration to give a signal proportional to ground displacement. The 1 s pendulum has negative feedback which allows simple damping arrangements and easy absolute calibration, as well as improving stability and linearity. A horizontal-component instrument has been built, but the principle should be equally applicable to measuring the vertical component.

An instrument for the determination of potassium in sodium chloride. By G. H. Laycock, A.Inst.P.

An instrument has been designed to measure the percentage of potassium in a 2·4 g sample of sodium chloride crystals in the range 0–4% with an accuracy of ±5%. A determination, which takes one minute, is made by recording photoelectrically the light scattered by suspended particles of potassium cobaltinitrite obtained by the addition of sodium cobaltinitrite solution to the dissolved sample. The instrument, which includes a novel device for dispensing a fixed quantity of reagent, can be used to determine the percentage of other impurities in other substances by selecting suitable reagents.

An electrodeless method for the measurement of electrolytic conductivity and magnetic susceptibility. By W. R. Myers. A.Inst.P.

Simultaneous measurement of electrolytic conductivity and magnetic susceptibility is achieved by observing the changes in output voltage of a transformer when its air core is filled with a specimen. Conductivity measurements for strong electrolytes have been obtained in which departures from accepted values are less than 0·07 mho m^{-1} in the range 1 to 30 mho m^{-1}. The magnetic measurements generally have less precision, and errors of 2% occur for susceptibilities of the order of 10^{-11} hm^{-1}.

A beam-scanned rotating heavy-ice target for high loads. By J. H. Spaa.

From the several possible targets for the $D(d,n)^3He$ reaction the heavy-ice target proves to be the most suitable for outputs of about 10^{10} neutrons per second. Beam scanning in two perpendicular directions combined with rotation of the target is found to be necessary to secure a sufficient life of the ice surface.

A high stability mains-operated recording thermistor thermometer. By A. W. Melville.

A simple record thermometer is described which is mains operated, has a total variation of less than 1% for a main variation of 10% and a warm up time of less than 5 min. With the given constants full scale deflection corresponds to 10°F. Any suitable 1ma. recorder may be used.

British Journal of Applied Physics: Volume 9, No. 5

SPECIAL ARTICLE

Physical methods of investigating chemical problems. By R. J. Taylor, F.Inst.P.

The scope that exists for physicists in chemical research is greater than many physicists realize. Applications of physical methods to chemical problems have increased rapidly during recent years and a wide literature has grown up around them. A brief review of physical techniques in current use is given, together with a detailed illustrative study of two problems, the removal of fishy flavour from vitamin A oils, and the relationship of polymorphic form to the characteristics of glyceride oils. The study is treated discursively to bring in matters of related interest.

ORIGINAL CONTRIBUTIONS

The photoelastic behaviour of cross-linked polymers. By Z. Tuzi, K. Kawata, and I. Hori.

The photoelastic and mechanical properties of various cross-linked polymers have been studied over a wide range of temperature. A large change of the stress-optical coefficient was observed in the second order transition region. At temperatures above that region, suitably cross-linked polymers show a photoelastic behaviour corresponding to nearly perfect entropy-elasticity. The effect of cross-linkage on the stress-optical coefficient has been studied in styrene-divinyl-benzene copolymers. The DVB content affects the coefficient considerably in the entropy-elasticity region, but negligibly in the glassy state.

From photoelastic data, one may derive the value of the optical anisotropy $(\alpha_1 - \alpha_2)$. The value of $\Delta n/S$ extrapolated to zero degree of cross-linkage agrees well with that of the linear polymer.

Experimental evidence is given that polymers formed by polymerization or addition reactions are preferable to those formed by condensation as materials for the stress-freezing method.

Calculated and observed effects of texture on the magnetic properties and Young's modulus of nickel sheet. By E. R. W. Jones, C. A. Clark, A.Inst.P., and E. A. Fell.

Relative values of Young's modulus, magnetostrictive coupling coefficient and initial and maximum permeabilities are calculated for various textures in nickel, an approximate model being used for magnetic properties.

Experimental values are given for high purity polycrystalline nickel sheet produced by powder metallurgy and annealed in purified hydrogen. Comparison between theory and experiment indicates good agreement for Young's modulus and fair agreement for magnetic properties. The textures were determined by X-ray photographic techniques and it was shown that strip possessing a cube recrystallized texture gave lower properties than recrystallized strip having a random grain orientation. It was also found, in agreement with previous work on copper, that the perfection of the cube texture was mainly governed by the temperature of anneal.

Prismatic fin with non-linear heat loss analysed by resistance network and iterative analogue computer. By I. C. Hutcheon and D. B. Spalding.

The paper analyses heat flow by natural convection from a fin of uniform conductivity and cross-sectional area, fixed at one end to a hot wall and immersed in a cooler fluid. A resistance network analogue is used in conjunction with a new type of iterative analogue computer to determine the temperature distributions and fin efficiencies for a variety of fin proportions, on the assumption that heat loss is proportional to the local temperature to the power 5/4. Results are compared with the case of linear heat loss.

A portable lamination detector for steel sheet. By B. O. Smith, A.Inst.P., A. P. H. Jennings, A.Inst.P., and A. G. Grimshaw.

This paper describes a method of detecting laminations in steel sheet based on the distortion they cause in the flow pattern of an electric current through the sheet. Direct current is passed through the sheet between two contacts on opposing faces while the potential difference between two adjacent contacts is measured. This potential difference is very small in sound material but rises sharply if a lamination is present.

Not every lamination can be detected by this method because, for this to happen, it is essential that it should form an electrical discontinuity. For example, experience has shown that in hot-rolled strip most of the laminations are not detected, but in cold-rolled strip the great majority above 0·25 in. wide do form a discontinuity and can be detected with certainty by the instrument described.

The high temperature stability of permanent magnets of the iron-nickel-aluminium system. By A. G. Clegg, and M. McCaig, F.Inst.P.

The open circuit magnetization of rectangular bars of various modern permanent magnet alloys has been measured at temperatures up to 550°C. A differential ballistic method has been used and, after magnetization at room temperature, both reversible and irreversible losses occur on heating. These losses vary with material and dimension ratio, and in an attempt to explain these variations demagnetization curves at 500° C have been measured. To avoid the irreversible losses, stabilization at a higher temperature is better than ageing in an alternating field.

A note on the adhesion of elastic solids. By K. L. Johnson.

A theoretical analysis is made of the stresses acting at the contact surface of two elastic spheres which are assumed to adhere to each other after the force pressing them together has been removed. The stress at the perifery of the contact area is shown to be tensile and infinite, so that adhesion is physically impossible ; the spheres would peel apart. The theoretical results are consistent with the experimental work of Bowden and Taylor.

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Applications, or requests for further information are invited from Engineers and Physicists with an honours degree or equivalent for senior and intermediate Engineer vacancies and from those who hold H.N.C. or O.N.C. for Assistant level posts. The rewards will be hard and interesting work, security, and a good salary which will be reviewed annually. Posts based at Brentford, Feltham, Sunbury-on-Thames, Bracknell Berks and Stonehouse, Glos.

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Applicants should have an honours degree in Physics or an equivalent qualification. The successful applicant is expected to take up duties on September 1, 1958.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. The closing date for the receipt of applications in Hong Kong and London is May 30, 1958.

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(University of London)

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Monday, September 29, 1958

Part-time (evening) courses provided for Internal degrees in the Faculties of Arts and Science. Facilities also provided for full-time and part-time students reading for :

(i) Higher degrees by thesis in Arts and Science,

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(iii) Academic postgraduate Diplomas in Psychology and Numerical Analysis.

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The Department of Scientific and Industrial Research has accepted the Postgraduate Diploma courses in Psychology and Numerical Analysis, and the M.Sc. Crystallography course, as suitable for tenure of its advanced course studentships. Students intending to read for Higher Degrees in Science by thesis are invited to inquire of the College whether it has available any D.S.I.R. Research Studentships.

Applications for admission to the College should be made before June 1. Pamphlet and form of application may be obtained from the Registrar, Birkbeck College, Malet Street, W.C.1.

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Applications are invited for University Studentships and Fellowships for experimental or theoretical research in Solid State Physics.

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Applications stating age, academic qualifications, research experience and names of two referees, should be sent to the Professor of Natural Philosophy, The University, Glasgow, W.2, before June 7, 1958.

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(5) PHYSICIST with particular interest in classical physics for fundamental research connected with the industrial processes referred to under (4).

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This list is representative rather than complete and general applications are invited. There are also other vacancies for work in the same fields for those with a pass degree or similar type of qualification.

Applications are invited from anyone who expects to be available before the end of 1958, including those doing National Service. The upper age limit is about 32, and starting salaries of up to £750 will be paid to newly-qualified graduates, up to £900 to newly-qualified Ph.D.'s, and up to £1,250 to more experienced applicants. A continuing and progressive career is offered, and the posts carry superannuation benefits under F.S.S.U. Experience of textiles is not necessary. Much of the work is likely to lead to publication, which the Institute encourages.

Applications to : Director, Shirley Institute, Didsbury, Manchester, 20.

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Apply in writing, stating age, qualifications and previous experience, to the Personnel Manager, Ferodo Ltd., Chapel-en-le-Frith, Via Stockport.

UNIVERSITY OF NATAL
SOUTH AFRICA

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Senior Lecturer in Physics—Pietermaritzburg
Lecturer in Physics—Durban
Lecturer in Physics—Pietermaritzburg.

The salary scales attached to the above posts are as follows :—Senior Lecturer £1,050 × £50–£1,600 per annum ; Lecturer £800 × £50–£1,200 per annum. The commencing notch on the above salary scales will be dependent on qualifications and/or experience. In addition to the salary scales indicated a temporary cost of living allowance of £234 per annum is payable to married men only.
Application forms and further particulars of the posts, including the commencing dates etc., are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London, on June 20, 1958.

MEMORIAL UNIVERSITY OF NEWFOUNDLAND
ST. JOHN'S NEWFOUNDLAND, CANADA

Applications are invited for the post of ASSISTANT PROFESSOR in the DEPARTMENT OF PHYSICS.
The current salary scales are under review but appointment will be made at not less than $5,000 a year ; depending on qualifications, etc., appointment may be made at a higher figure.
There is provision for contribution towards transportation expenses and a liberal contributory Pension Plan exists.
Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.
The closing date for the receipt of applications, in Canada and London, is June 30, 1958.

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR

Applications are invited for the post of ASSISTANT LECTURER in PHYSICS.
The salary scale is £700 × £50–£850 p.a., and in addition there are F.S.S.U. benefits and family allowances. The appointment will date from October 1, 1958.
Two copies of the application should reach the undersigned, from whom further particulars may be obtained not later than June 9, 1958.

Kenneth Lawrence,
Secretary and Registrar.

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A suitable candidate would be a man or woman with a First or Second Class Honours in Physics, preferably with some subsequent research experience. A knowledge of statistical methods is essential and experience in electronic equipment would be an advantage. The work involved will be the development of new methods of Quality Control and Automatic Control and the application of these methods to existing and newly developed processes of manufacture.

The Research and Development Establishment is pleasantly situated on the west side of Southampton, within easy reach of the New Forest and runs its own canteen. A 5-day week and contributory pensions scheme are in operation. The Establishment is relatively new and the prospects for a keen and hard worker are excellent.

Applications should be addressed to : Personnel Department, British-American Tobacco Co., Ltd., Westminster House, P.O. Box 482, Millbank, London, S.W.1.

UNIVERSITY OF NATAL
SOUTH AFRICA

Applications are invited from suitably qualified persons for appointment to the following vacant Chairs on the fixed establishment of the University :—

Chair of Mathematics (Pure and/or Applied)—Durban or Pietermaritzburg.

Chair of Experimental Physics—Durban.

The salary scale attached to the above posts is £1,400 × £50–£2,000 per annum. The commencing notch on the above salary scale will be dependent on qualifications and/or experience.

In addition to the salary scales indicated a temporary cost of living allowance of £234 per annum is payable to married men only.

Application forms and further particulars of these posts, including the commencing dates, etc., are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London, on June 30, 1958.

UNIVERSITY COLLEGE OF NORTH WALES
BANGOR

Applications are invited for the post of ASSISTANT LECTURER in MATHEMATICS. Preference will be given to candidates with research experience.

The salary scale is £700 × £50–£850 p.a., and in addition there are F.S.S.U. benefits and family allowances. The appointment will date from October 1, 1958.

Two copies of the application should reach the undersigned, from whom further particulars may be obtained, not later than June 2, 1958.

Kenneth Lawrence,
Secretary and Registrar.

MONMOUTHSHIRE EDUCATION COMMITTEE
THE TECHNICAL COLLEGE OF MONMOUTHSHIRE, CRUMLIN
Principal : Dr. T. V. Starkey, F.Ins.P.

Required for September 1 next, an Assistant Lecturer to teach Physics with some Mathematics at Ordinary National Certificate standard. Candidates must hold a good degree or equivalent qualification, e.g. Grad.Inst.P., and industrial research and/or teaching experience is desirable.

Salary in accordance with the Burnham Scale for Assistant Lecturers Grade B.

Forms of application and further particulars obtainable from the undersigned to whom completed forms should be returned not later than May 31, 1958.

T. M. Morgan,
Director of Education.

County Hall,
Newport, Mon.

COURSES

MIDDLESEX COUNTY COUNCIL
EDUCATION COMMITTEE
BRUNEL COLLEGE OF TECHNOLOGY,
WOODLANDS AVENUE, ACTON, W.3.
(Tel. : ACOrn 6661)

Principal : J. Topping, M.Sc., Ph.D., D.I.C., F.Inst.P.
Head of Mathematics Department : J. Crank, M.Sc., D.Sc., F.Inst.P.

MATHEMATICS FOR INDUSTRY

A four-year sandwich course in Mathematics for the Diploma in Technology will commence in September, 1958. Modern Applied Mathematics, practical Computation and Statistics are vital parts of the course, supported by relevant sections of Pure Mathematics, Physics and Electronics. The course is open to employees of firms willing to maintain them and also to school-leavers.

Details may be obtained from the Head of the Mathematics Department to whom early application should be made.

C. E. Gurr, M.Sc., Ph.D.,
Secretary to the Education Committee.

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COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

SOIL MECHANICS SECTION

Appointment No. 270/178 of Physicist or Engineer

Applications are invited for appointment to a position of Physicist or Engineer with the Organization's Soil Mechanics Section which will be at Syndal, Victoria, but the appointee will be expected to visit all states of Australia to initiate and supervise collaborative projects. The appointee will be responsible for the direction of a small group and the co-ordination of activities of other groups in investigations into the general problem of defining the mechanisms, magnitude and engineering significance of water movements in soils beneath pavements and buildings. Initially to implement a programme of applied soil physics investigations aimed at defining the moisture status of pavement subgrades in representative areas throughout the whole of Australia.

Applicants should possess a University degree in Engineering and additional training in Physics, or alternatively, a degree in Science with Physics as a major subject and with some additional Engineering training. A knowledge of the problems of pavement design for roads and airfields is essential. A familiarity with the problems of design and use of electronic equipment is also necessary. An understanding of the current techniques of soil physics is desirable. The appointee must have had extensive experience in soil investigations related to pavement construction, with particular emphasis on subgrade moisture studies. Experience in the direction of a technical staff and the ability to collaborate with technical workers in a number of organizations are both essential qualifications.

Appointment will be made according to qualifications and experience within the ranges of £A1,773–£1,993, Experimental Officer Grade III, or £A2,103–£2,323 p.a., Senior Experimental Officer. Salary for a female appointee would be £A167 p.a. less than the corresponding male rates.

The appointment will be conditional upon a satisfactory medical examination and appointment carries with it Commonwealth Superannuation Fund or Commonwealth Provident Account privileges.

An appointee migrating from overseas will be eligible for tourist class sea or air transport to Australia for himself, his wife and family. An appropriate contribution will also be made towards the fares of an Australian appointee, his wife and family temporarily abroad for study or similar purposes.

Applications quoting Appointment No. 270/178 and stating full name, place, date and year of birth, nationality, marital state, present employment, details of qualifications and experience, and of war service if any, together with the names of not more than four persons acquainted with the applicant's academic and professional standing, should reach the undersigned from whom further particulars may be obtained, by June 30, 1958.

A. Shavitsky,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Applications invited from honours graduates for bursaries £400–£500 p.a. to carry out fundamental research, normally leading to Ph.D., on mechanisms of combustion, propagation of smouldering, and ion plasmas of flames. Applications indicating qualifications and experience to Dr. J. H. Burgoyne, Department of Chemical Engineering, Imperial College, London, S.W.7.

NORTH STAFFORDSHIRE TECHNICAL COLLEGE

STOKE-ON-TRENT

Principal : H. W. Webb, O.B.E., D.Sc., F.R.I.C., M.I.Chem.E., F.I.Ceram.

PHYSICS DEPARTMENT

Applications are invited for the post of assistant lecturer Grade "B" to commence on September 1, 1958. Duties will include the teaching of Physics at all standards up to Higher National Certificate. Applicants should possess a good honours degree in Physics and be interested in the application of Physics in industry. Industrial and/or teaching experience would be an advantage.

Salary scale £650 to £1,025 with appropriate allowances for degree and previous experience where applicable.

Applications giving full details of training, experience and particular fields of interest should be sent to the Principal immediately, together with the names of two referees.

H. Dibden,
Clerk to the Governors.

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The men we are seeking should have an Honours degree in Physics or have passed the Graduateship examination of the Institute of Physics. They should preferably be under 30 years of age.

The salaries are excellent and every opportunity exists for a satisfying career with a major and progressive company in an expanding industry. The working conditions are good and a pension scheme is operated. Write, giving brief details about your education and experience, and quoting Ref. No. E.P.5 (on the letter and envelope, please) to The Manager, Training and Personnel Division, The British Tabulating Machine Company, Ltd., 17 Park Lane, London, W.1.

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Broad Street House, 54 Old Broad Street, London, E.C.2
(Telephone : LONdon Wall 7007/8)

UNIVERSITY OF DURHAM
KING'S COLLEGE, NEWCASTLE UPON TYNE

Applications are invited for a Temporary Fellowship in the Department of Physics. The Fellow will be expected to carry out a research programme on paramagnetic resonance in semiconductors. Candidates should have a Ph.D. in Physics and preferably several years' additional research experience in solid state physics, in magnetic resonance, or in low temperature physics. Stipend up to £1,000 per annum plus F.S.S.U. depending on age and qualifications. Applications, together with the name of two referees should be submitted as soon as possible to the undersigned from whom further particulars may be obtained.

G. R. Hanson,
Registrar of King's College.

BRITISH PETROLEUM COMPANY LIMITED has a vacancy for an Honours Graduate in Physics at its Exploration Research laboratories at Sunbury-on-Thames. Work concerns research into the application of nuclear physics for measurements in oil and gas reservoirs. Both natural radioactivity and induced activity by neutron bombardment are studied. Short visits overseas may be necessary to test borehole instruments developed. A knowledge of electronics and counting techniques is essential. Salary according to age, qualifications and experience. Non-contributory Pension Fund, Assisted House Purchase Scheme. Removal expenses and settling-in allowance payable in certain cases. Luncheon Club. Write, giving full details, quoting reference H.4433, to The Manager, Recruitment Branch, The British Petroleum Company Ltd., Britannic House, Finsbury Circus, London, E.C.2.

SENIOR SCIENTIFIC and SCIENTIFIC OFFICERS required in Scientific Adviser's Department, Air Ministry. Qualifications: 1st or 2nd class honours degree in Mathematics, Statistics, physical sciences such as Physics, Engineering; natural sciences such as Biology or social sciences such as Economics. Appointments offer great scope and interest to versatile scientists capable of working well with Service Officers and of adopting methods suited to Service environment. Work mainly Operational Research in wide variety of subjects of concern to the R.A.F. including tactics, technical development and logistics. Offering S.O. entrants valuable experience in principles of Operational Research. Salaries in London for S.S.O. are £1,190–£1,410 and S.O. £635–£1,110. Outside London and for women, salaries slightly lower. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, S.W.1 (Quoting A158/8A)

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Applications are invited for a number of posts in the development laboratory of this Company. Successful candidates would work as members of a team engaged in the application of the techniques of nuclear physics to a wide range of problems. A degree in physics is necessary and one or two years' experience of research or development work in similar fields would be an advantage. The company offers attractive salaries and working conditions and the positions will provide ample scope for advancement in this rapidly expanding industry. Applications to The Personnel Manager, Plessey Nucleonics Ltd., Weedon Road, Northampton.